THE IDENTIFICATION AND APPLICATION OF SOLUTIONS TO INCREASE ENERGY EFFICIENCY IN AN AGRO-FOOD MARKET

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Abstract: The modernization and reconfiguration of the interior commercial of the agro-food hall in the Central Market of Petroșani, aiming to align with European regulations, increase the number of traders and a better sectorization of the market, have led to a continuous increase in electricity consumption. In order to stop this growth and to keep the dynamic of electricity consumption on a downward slope, in the past years a number of organizational and technical solutions have been implemented, which have led to a reduction of own electricity consumption by approximately 74%.

Keywords: installed power, demand coefficient, neutral power factor, energy balance.

1. INTRODUCTION

The development and analysis of electrical energy balances is a scientific method for assesing the energy-economic efficiency of technological processes, in order to improve the yelds of energy-consuming machines, raising the technical-economic level of their exploitation and perfecting the energy supply schemes for energy consumers [15], [18]. Balance sheets can be prepared for industrial installations, for lighting installations or for installations of administrative and residential buildings [11], [27]. One of the criteria for differentiating the balance sheets is the volume of the installation they refer to. In this sense, the notion of the balance outline is defined as the conventional surface that includes the limits of the installation against which the inputs and outputs of energy are considered [4], [19].

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Within the power balances, the basic information concerns the quantities related to the consumption of electricity and the conditions in which in takes place. It is therefore necessary that, depending on the configuration of the distribution installation, there is the posibility of measuring different electric parameters such as: active and reactive energy, voltages, currents, powers and especially maximum active powers, and for these, the proper measuring instruments should be provided [9]. The minimum list of parameters to be measured consists of active energies, reactive energies and voltages at certain points [13], [20].

If the balances are drawn up for a day, the variation of the parameters can be observed hourly, as the energies and voltages values can be read after each hour. In this way, determining the average powers, the active and reactive load curves can be drawn for each day which is set to perform the measurements. With these curves, a series of useful values and indicators can be determined such as: maximum / minimum / average powers, power factor, duration of instalation's functioning at maximum powers.

Electric lighting can be the subject of a separate balance sheet, in order to know the operating regimes of instalations that use lighting fixtures with gas discharges, measurements of active and reactive energy are performed in order to be able to draw the load curves and determine the power factor [1], [21].

2. PRESENTATION OF THE AGRO- FOOD HALL

Public Service Market Administration P.S.M.A. (or S.P.A.P. in Romanian) in Petroșani is a public institution that administrates the three agro-food markets located in the municipality of Petroșani. Of these, the Central Market is the largest, comprising an agro-food hall, a sector for the sale of fruits, vegetables and cereals, a sector for sale of non-food and industrial products and a parking lot.

The biggest consumer of electricity in the Central Market is the agro-food hall, which includes: administration offices and the sanitary group; two batteries of booths for selling meet, cheese, dairy and honey, located on the hall's ground level, on the eastern, respectively western side; two batteries of kiosks for selling non-food products, located at the two mezzanines; a platform with tables for selling fruits, vegetables and cereals, located in the central zone of the ground level.

A mechanical maintenance workshop can be found at the basement of the agro-hall, on the northern side.

3. THE PRE-EXISTING SITUATION

Between 2002-2013, the electricity consumption of the agro-food hall within the Central Market marked a significant increase compared to the period before 2002, an increase which had its main cause the appearance of new consumption points (new batteries of booths and kiosks built inside the hall, expansion of the Administration offices, expansion and reconfiguration of lighting instalations).

In addition to the electrical equipments necessary for carrying out commercial activities (mainly refrigeration equipments), the Administration's offices were heated during the winter with electrical radiators and convectors. In this way, the daily electricity consumption during the winter reached values of 3-400 kWh, making electricity bills to represent approximately 20% of the Administration's total budget, which was totally unacceptable.

Back in 2013, the installed active powers of the facilities connected in the three-phase connection of the agro-food hall were those shown in table 1.

Table 1. ***The installed active powers of the electrical installation connected to the general power supply of the agro- food hall back in 2013***

No.	Electrical Facilities	Installed Active Power (kWh)
1	General lighting installations in common spaces and circulation paths in the agro- food hall	3,5
2	Electrical installations for lighting and power in 28 commercial booths	28
3	Electrical instalations for lighting and power in administrative spaces and for other purposes outside of commercial activities (Administration offices, mechanical maintenance workshop, toilets)	21,6
TOTAL INSTALLED ACTIVE POWER		53,1

Since there are no recorded data from that period regarding the operate regime of the electrical equipments and their simultaneity and demand coefficients can't be determined, we can't know precisely what was the average power absorbed instantaneously, but if we bear in mind that the maximum instantaneous power approved by contract is 30 kW, we can assume that this power was not exceeded at any time, since no overload tripping of the principal circuit breaker was reported. At the same time, the values of the power factor (cos φ) aren't known and it's not possible to estimate the consumption of inductive reactive energy [14], [22], [28].

4. ENERGY CONSUMPTION EFFICIENCY MEASURES

In the context of the situation already presented and given the fact that the price of electricity has continuosly increased, the need to find effective solutions to reduce electricity bills has become more and more important [6], [23]. The first solution was implemented at the beginning of 2014, through the purchase and installation of a centralized natural gas heating system for the area of the Administration offices and the sanitary group. In this way, the total installed active power decreased by approximately 10 kW.

In the summer of 2015, a number of 22 booths out of the 28 for agricultural producers were disconnected from the common three-phase electrical column which was connected to the Administration's own electrical connection and were connected directly to the network of the local distribution operator *E-Distribuție Banat* through individual electrical connections [5], [25]. In this way, the producers using the booths pay for their own electricity consumption and the total installed active power of the market's electrical connection decreased by another 22 kW.

Between 2018-2022, all the lighting fixtures installed on the common circulation paths, as well as those in the Administration's offices, mechanical maintenance workshop and toilets were modernized by replacing the classic electric bulbs and fluorescent tubes with bulb-type LED and LED tubes [4], [24]. In this way, the total installed active power has decreased by another 2 kW and at the end of 2022 the situation of installed active powers was as shown in table 2.

Table 2. ***The installed active powers of the electrical installation connected to the general power supply of the agro- food hall at the end of 2022***

No.	Electrical Facilities	Installed Active Power (kWh)
1	General lighting installations in common spaces and circulation paths in the agro- food hall	1,5
2	Electrical installations for lighting and power in 6 commercial booths	6
3	Electrical instalations for lighting and power in administrative spaces and for other purposes outside of commercial activities (Administration offices, mechanical maintenance workshop, toilets)	11,6
TOTAL INSTALLED ACTIVE POWER		13,7

The most recent measure undertaken to reduce electricity consumption was implemented in the fall of 2022 and aimed at reducing the demand coefficient in the electricity supply of lighting. Thus, the manual control of the lamp lines mounted on the common traffic paths was abandoned and an automatic control system was implemented by means of an hourly switch and a twilight switch. In this way, the switching on and off of the lamps is done according to an algorithm based on a combination of the level of the external natural lighting and the operating hours of the agro-food hall, independently of the human factor [7],[8].

5. RESULTS OBTAINED. PREPARATION OF THE ELECTRICAL ENERGY BALANCE

As can be seen by comparing the data in tables 1 and 2, the measures implemented and mentioned above led to a decrease of approximately 74% of the total installed active power on the three-phase connection of the agro-food hall. In order to have further confirmation of the effectiveness of these measures, we wanted to see if the efficiency of the use of electricity also improved with the decrease in consumption. For this, it was necessary to draw up an energy balance [2],[10]. The detailed outline of the balance included the following electrical installations:

- The electrical installation for lighting and power in the Administration's offices;
- The electrical installations for lighting and power for refrigerators, scales and cash registers in 6 commercial booths;
- The electrical installations for lighting and power in the mechanical maintenance workshop;

- The electrical installations for lighting on the main circulation paths of the agro-food hall;
- The electrical installations for lighting in the toilet rooms;
- The electrical security lighting installation for emergency evacuation, with light-blocks powered by local batteries.

Receptors consuming electricity consist of: electronic equipments (office-computers, faxes and printers- cash registers, electronic scales); different electrical tools; electrical appliances for refrigerating and heating; LED lighting fixtures.

a) b)

Fig.1. a) Digital meter CST 0410L D; b) Digital multimeter BENNING MM 1-1

Electricity is supplied from the transformer station belonging to *E-Distribuție Banat*, through a cable type ACYABY 3x50 mm^2 + 25 mm^2, about 20 m long. The cable is mounted on non-combustible building structures. The installed power aproved by the contract is P_i=30 kW. The measurement of the consumed energy is done at the connection point by means of a three-phase electronic meter CST 0410L D (fig. 1a), which allows succesive reading of 3 quadrants [16]:

- Installed power $\boldsymbol{P_i}$;
- Total active energy $\boldsymbol{E_a}$;
- Total reactive energy $\boldsymbol{E_r}$.

Apart from these parameters measured directly by the CST 0410L D meter, for drawing up the balance it is also necessary to measure the line voltage $\boldsymbol{U_l}$ and then to determine the instantaneous absorbed current (the demanded current) $\boldsymbol{I_c}$ at the connection point. For voltage measurements we used a BENNING MM 1-1 digital multimeter (fig. 1 b) [17].

The electric energy balance was drown up for the time interval 7:00h - 19:00h, which corresponds to the ”open for public” schedule of the agro-food hall. The measurements and data collection took place on December 15, 2022, every hour of the above mentioned time interval. We measured: total active energy, total reactive energy and line voltage. We considered the time interval between two measurements as operating time $\boldsymbol{T_f}$ of the installation; T_f = 1 hour [1],[2].

Based on these measurements we determined the following data for each individual hour:

- Hourly consumption of active energy ***ΔE*** ΔE_a, which is the difference between two consecutive hourly values of active energy shown by the meter;
- Hourly consumption of reactive energy ΔE_r, which is the difference between two consecutive hourly values of reactive energy shown by the meter;
- Hourly power factor ***cos φ***, calculated with the following formula:

$$\cos\varphi=\frac{1}{\sqrt{1+\left(\frac{\Delta Er}{\Delta Ea}\right)^2}} \tag{1}$$

- Instantaneous absorbed active power (demanded active power) P_c, calculated with the following formula:

$$P_c=\frac{\Delta Ea}{Tf} \tag{2}$$

- The demand coefficient K_c, calculated with the following formula:

$$K_c=\frac{P_c}{P_i} \tag{3}$$

- Instantaneous absorbed current (demanded current) I_c, calculated with the following formula:

$$I_c=\frac{P_c}{\sqrt{3}U_1\cos\varphi} \tag{4}$$

Determining the power factor as accurately as posible is very important, as it provides the user of electricity with information regarding a possible need to install equipments to compensate losses through inductive reactive energy. As we know, the National Energy Regulatory Authority (A.N.R.E.) issued Order no. 76/2016, valid from January 1, 2017, which amended and supplemented the ***Methodology regarding the establishment of payment obligations for reactive energy and the regulated price for reactive energy***, approved by the Order of the President of A.N.R.E., no. 33/2014 [12], [26].

Thus, a new reference value of the former neutral power factor (now renamed ***limiting power factor***) was established, decreasing from value 0,92 to the new value 0,9. This value represents the lower limit of the power factor from which invoicing of inductive reactive power consumption begins for non-domestic consumers connected to the public distribution network through three- phase connections.

The data obtained by measurements and calculations were sumarized in table 3.

Based on these summaries, we drew up a series of load graphs that illustrate the variations in active (fig. 2) and reactive (fig.3) energy consumption, but also the evolution of the demand coefficient (fig. 4) during a working day.

Analyzing the three graphs, it can be seen that their shapes are almost identical. This is due to the fact that the power factor remained constant during the entire working day. At the same time, the demand coefficient, although it recorded large variations during the entire working day, it reached at 1:00 PM its maximum value of

0,4, which corresponds to a maximum active power absorbed instantaneously of only 40% of the connection's installed active power [3].

Table 3. ***The data required for the preparation of the electrical energy balance, obtained through measurements and calculations on December 15, 2022***

Hour	**U_l (V)**	**E_a (kWh)**	**ΔE_a (kWh**	**E_r (kVAR)**	**ΔE_r (kVAR)**	**P_c (kW)**	**I_c (A)**	**K_c**	**cos φ**
7	422	647767	-	62353,98	-	-	-	-	-
8	423	647777	10	62357,98	4	10	14,70	0,33	0,93
9	421	647788	11	62362,36	4,38	11	16,24	0,37	0.93
10	423	647798	10	62366,34	3,98	10	14,70	0,33	0,93
11	424	647808	10	62370,32	3,98	10	14,66	0,33	0,93
12	419	647811	3	62371,52	1,52	3	4,45	0,1	0,93
13	422	647823	12	62376,29	4,77	12	17,67	0,4	0,93
14	420	647827	4	62377,88	1,59	4	5,92	0,13	0,93
15	423	647835	8	62381,07	3,19	8	11,76	0,27	0,93
16	424	647839	4	62382,66	1,59	4	5,86	0,13	0,93
17	422	647841	2	62383,45	0,79	2	2,95	0,07	0,93
18	425	647843	2	62384,24	0,79	2	2,92	0,07	0,93
19	420	647845	2	62384,03	0,79	2	2,96	0,07	0,93

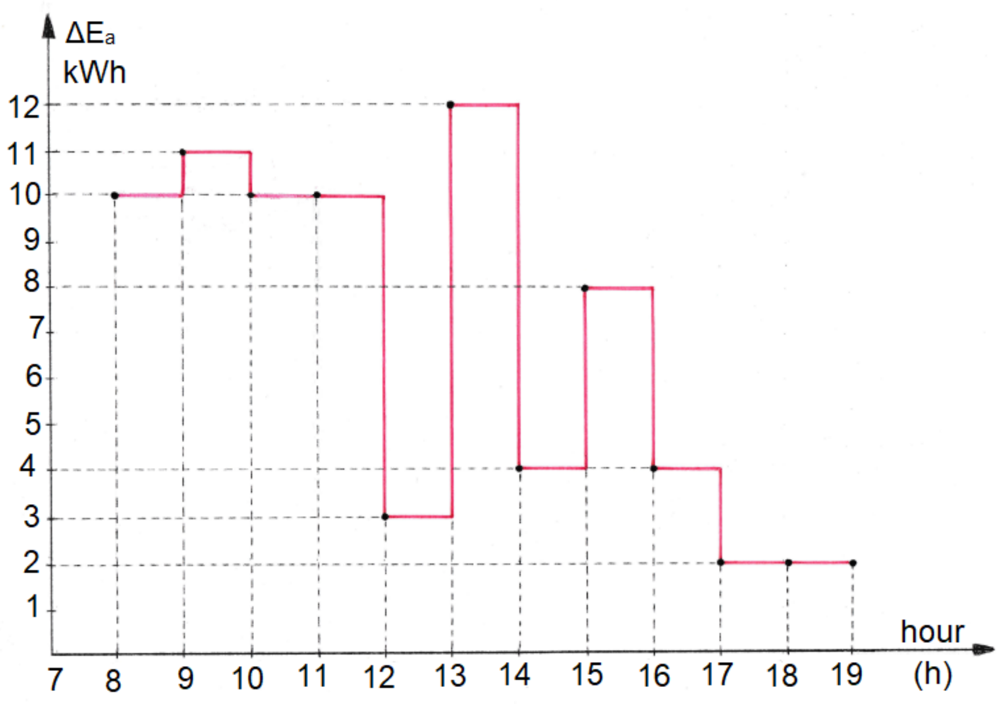

Fig.2. Active energy consumption variation graph

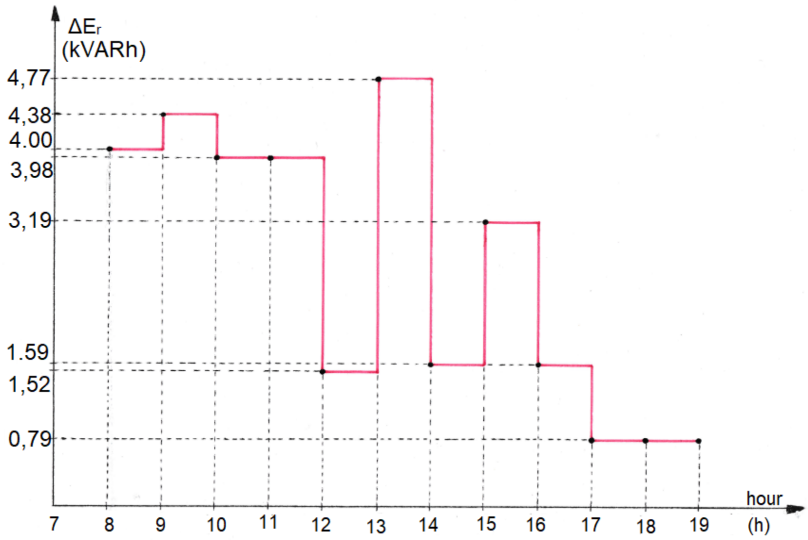

Fig. 3. Reactive energy consumption variation graph

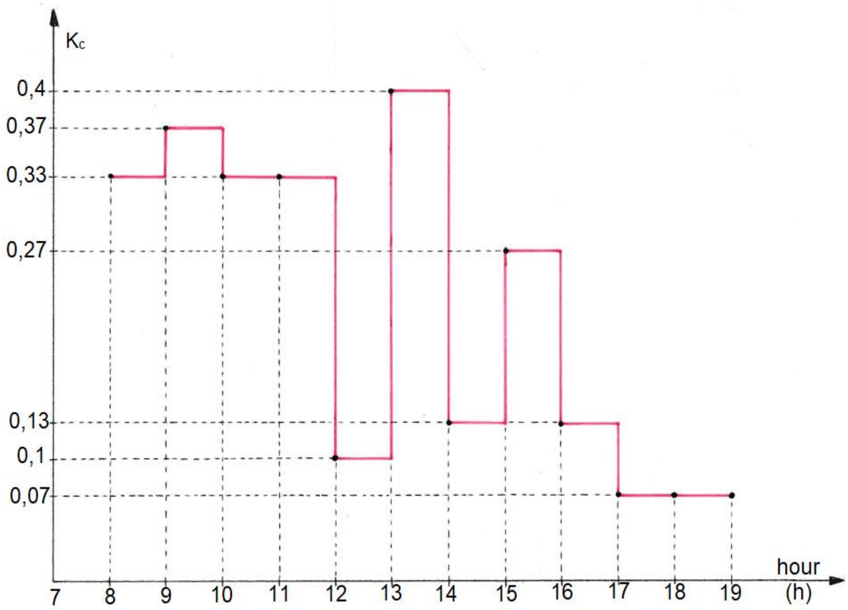

Fig.4. Demand coefficient variation graph

6. CONCLUSIONS

The data collected during the preliminary operations for drawing up the energy balance show unequivocally that all the actions taken in previous years, regarding the reduction of electricity consumption and the optimization of the operation of the electrical installations in the agro-food hall of the Central Market in Petroșani have achieved their goals, leading to:

- Raising the value of the power factor to 0,93, which is higher than the limit power factor of 0,9. This means that the consumption of reactive energy is not invoiced, thus achieving an important economy in the electricity expenses of the S.P.A.P. in Petroșani, especially in the current context of the huge increase in electricity costs;
- The sharp decrease in the instantaneously absorbed active power (demanded active power) during all operating hours of the electrical installations. Thus, the highest value of the demand coefficent was only 0,4. Due to this fact, we have reached the situation where there is no need to undertake any additional measures regarding the transfer of some electricity consumptions from an hourly interval to another in which the consumptions are lower;
- The complete elimination of the posibility of overloading the electrical installations, with beneficial effects in the technical conditions of the circuits, but also in the security of the electrical installations' users.

We can conclude, therefore, that the electrical installations in the agro-food hall of the Central Market in Petroșani are efficient and safe to operate.

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